ON THE REACTIVITY OF HALO-1,3-AZOLES AND RELATED COMPOUNDS TOWARD AROMATIC S_N2 SUBSTITUTION

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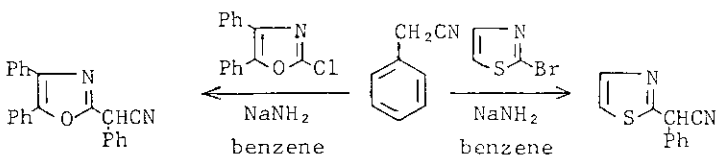
Abstract —— Nucleophilic addition-elimination reactions of 2-methylsulfonyl-1,3-azoles with active methylene compounds were investigated in order to compare the reactivity of substrates. The order of oxazole > thiazole >> N-methylimidazole in the reactivity was exhibited clearly. Furthermore, in oxazole and thiazole series, the predominant reactivity of the 2-position over the 4- and 5-positions was indicated on the reaction with the carbanions generated from active methylene compounds.

Synthesis of 1,3-azole derivatives containing a functionalized carbon side-chain by means of aromatic S_N2 type substitution of monohalo-1,3-azoles with active methylene compounds under basic conditions has not yet been well investigated, and the following only two reactions are reported in this category.[1,2]

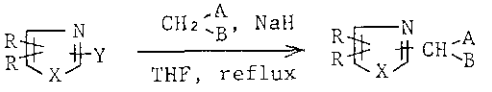


Scheme 1

In order to obtain utilizable information on the nucleophilic C-C bond formation from the viewpoint of the synthesis of 1,3-azole derivatives, we investigated the scope and limitations of the nucleophilic substitution of halo-1,3-azoles with active methylene compounds, together with the reaction of related compounds, as illustrated in Scheme 2.

In the present investigation, the relative reactivity of halo- and methylsulfonyl-azoles towards nucleophiles was qualitatively estimated on the basis of isolated yields of the products and the reaction time in which complete consumption of the substrates was detected with the aid of thin layer chromatography. When the reac-

tion was very slow, recovery yields of the substrates at 24 h were also taken as an additional index to evaluate the reactivity.



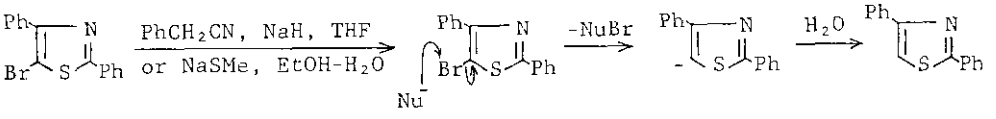
X=O (oxazole), S (thiazole), N-Me (1-methylimidazole)
R=H, Ph; Y=Cl, Br, SO_2Me
A and B = CN, CO_2Et, COMe, Ph

Scheme 2

Firstly, in order to estimate the difference on the reactivity of the 2-, 4-, and 5-positions of each 1,3-azoles, the reaction of phenylacetonitrile with a variety of positional isomers of halo-diphenyl-1,3-azoles was examined under reaction conditions mentioned in Scheme 2. As listed in Table I, all the substrates, except for 4-chloro-2,5-diphenyloxazole (**4Aa**), reacted with the phenylacetonitrile to give the desired compounds in considerable yields.

Judging from the yields and the required reaction time, it is clear that the relative reactivity in oxazole and thiazole series is in the order of position 2 > position 5 > position 4.

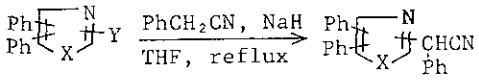
In connection with these results, it should be noted that the reaction of 4-halo-2,5-diphenyl- and 5-halo-2,4-diphenyl-1-methylimidazoles with active methylene compounds was not examined, because the preparation of these compounds was not established. Further, in the reaction of 5-bromo-2,4-diphenylthiazole (**7Ab**), a unique debromination happened instead of the formation of the expected product, and in this case 2,4-diphenylthiazole was isolated as a sole product. The same result was obtained by the reaction of **7Ab** with sodium methylthiolate in ethanol. Accordingly, a likely mechanism of debromination is given in Scheme 3 involving initial attack of nucleophites to a 4d orbital of the bromine atom.



7Ab

Scheme 3

Table I. Reaction of Halo-1,3-azoles with $PhCH_2CN$



1-7A 1-7Ca

Substrate				Product			
No.	X	Y	Position of Phenyl Groups	No.	Reaction Time (h)	mp (°C)	Yield (%)
1Aa	O	2-Cl	4 and 5	1Ca	1/4	115-117[a]	71
4Aa	O	4-Cl	2 and 5		24		0 (81)[b]
4Ab	O	4-Br	2 and 5	4Ca	20	170-171	47
6Aa	O	5-Cl	2 and 4	6Ca	3	114-115	56
6Ab	O	5-Br	2 and 4	6Ca	3	114-115	69
2Aa	S	2-Cl	4 and 5	2Ca	1/4	117-119	73
5Aa	S	4-Cl	2 and 5	5Ca	20	128-130	46
5Ab	S	4-Br	2 and 5	5Ca	4	128-130	51
7Aa	S	5-Cl	2 and 4	7Ca	2	120-121	58
3Aa	NMe	2-Cl	4 and 5	3Ca	2	168-170	78

a) Lit.[1] mp 109°C.

b) The figure in the parenthesis shows the recovery of substrate.

Secondly, in order to compare the nucleophilicity of active methylene compounds toward the 2-position of three kinds of 1,3-azoles, the reaction of 2-methylsulfonyl-4,5-diphenyl-1,3-azoles (1-4B) with such active methylene compounds as phenylacetonitrile (Ca), malononitrile (Cb), ethyl cyanoacetate (Cc), diethyl malonate (Cd), and acetylacetone (Ce) was examined in a similar manner as described in the preceding page.

As listed in Table II, the results obtained by these experiments suggest that phenylacetonitrile is most nucleophilic, whereas acetylacetone is least. The following order in the nucleophilicity of the active methylene compounds, which is essentially same to that observed on the reaction with six-membered N-heteroaromatics,[3] could be concluded.

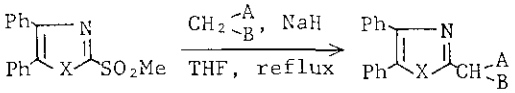
$^{-}CH(CN)Ph$ >> $^{-}CH(CN)_2$ > $^{-}CH(CN)CO_2Et$ > $^{-}CH(CO_2Et)_2$ >> $^{-}CH(COMe)_2$

In addition to the above observation, the following order was recognized in the reactivity of the 2-position of 1,3-azoles.

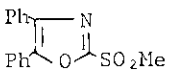
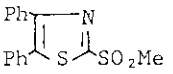
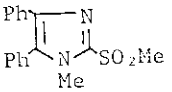
oxazole > thiazole >> imidazole (N-Me)

In these experiments, 2-methylsulfonyl derivatives were employed instead of the corresponding 2-halo derivatives, because the reaction of 2-chloro-4,5-diphenylthiazole (**2Aa**) with malononitrile resulted in the complete recovery of the chloride.

Table II. Reaction of 2-Methylsulfonyl-4,5-diphenyl-1,3-azoles with Active Methylene Compounds



1-3B **1-3C**

Nucleophile		$^{-}CH(CN)Ph$ (Ca)	$^{-}CH(CN)_2$ (Cb)	$^{-}CH(CN)CO_2Et$ (Cc)	$^{-}CH(CO_2Et)_2$ (Cd)	$^{-}CH(COMe)_2$ (Ce)
Substrate						
	Time (h)	1/12	1/4	2	5	10
	mp (°C)	115-117[a]	225(dec.)	167-168	syrup	99-100
1B	Yield (%)	74	71	63	52	68
	Time (h)	1/12	2	6	24	24
	mp (°C)	117-119	253(dec.)	210-212	124-125	
2B	Yield (%)	82	76	66	56	0 (63)[b]
	Time (h)	1/4	24	24		
	mp (°C)	168-170				
3B	Yield (%)	71	0 (59)[b]	0 (81)[b]		

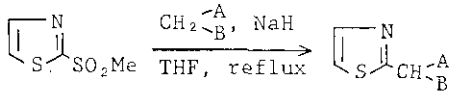
a) Lit.[1] mp 109°C.

b) The figures in parentheses show the recoveries of substrates.

Meanwhile, it was incomplete to prepare all kinds of diphenyl derivatives of 4- and 5-methylsulfonyl-1,3-azoles, owing to the unsuccessful reaction of the corresponding halides with sodium methylthiolate. On the basis of the results in Table I, however, it is conceivable that oxazole is less reactive than thiazole at the 4-position and that the reactivity of oxazole and thiazole is similar at the 5-position.

Thirdly, the reaction of 4,5-unsubstituted 2-methylsulfonylthiazole with active methylene compounds was examined. As listed in Table III, the results do not contradict with those obtained in the diphenylthiazole derivatives.

Table III. Reaction of 2-Methylsulfonylthiazoles with Active Methylene Compounds



8B 8C

Nucleophile	$^-CH(CN)Ph$ (Ca)	$^-CH(CN)_2$ (Cb)	$^-CH(CN)CO_2Et$ (Cc)	$^-CH(CO_2Et)_2$ (Cd)	$^-CH(COMe)_2$ (Ce)
Time (h)	1/4	2	5	24	24
mp (°C) or bp (°C)/(mmHg)	150/3[a]	220[b]	159-160	93-94	
Yield (%)	82	88	76	61	0 (71)[c]

a) Lit.[2] bp 154-156°C/4 mmHg.

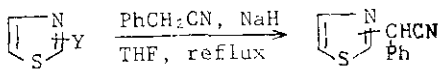
b) No melting point is reported in the literature.[4]

c) The figure in parenthesis shows the recovery of substrate.

Furthermore, the reaction of the positional isomers of monohalothiazoles not containing any other substituent with phenylacetonitrile exhibits that the relative reactivity of 2-, 4-, and 5-positions in thiazole rings is in the order of position 2 > position 5 > position 4. These findings are essentially same to those observed on halo-diphenyl derivatives of oxazole and thiazole.

Accordingly, it is clear that two phenyl groups attached to 1,3-azoles do not exert any particular substituent effect to aromatic S_N2 type reactions.

Table IV. Reaction of Halothiazoles with $PhCH_2CN$



8-10A 8-10Ca

Substrate		Product				Corresponding Diphenyl Derivative		
No.	Y	No.	Reaction Time (h)	mp (°C) or bp (°C)/(mmHg)	Yield (%)	No.	Reaction Time (h)	Yield (%)
8Aa	2-Cl	8Ca	1	150/3[a]	70	2Aa	1/4	73
8Ab	2-Br	8Ca	1	150/3[a]	73			
9Aa	4-Cl	9Ca	30	78-80	41	5Aa	20	46
9Ab	4-Br	9Ca	6	78-80	54	5Ab	4	51
10Ab	5-Br	10Ca	4	86-87	68	7Ab	2	58

a) Lit.[2] bp 154-156°C/4 mmHg.

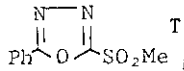
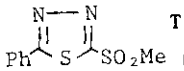
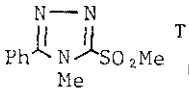
Finally, in order to confirm the general aspects of the reactivity indicated in *monocyclic* 1,3-azoles in other ring systems, the reaction of the corresponding 1,3,4-diazole and 1,3-benzazole derivatives with active methylene compounds was investigated. The substrates employed in this subject were 2-methylsulfonyl-5-phenyl-1,3,4-oxadiazole (11B), 2-methylsulfonyl-5-phenyl-1,3,4-thiadiazole (12B), 4-methyl-3-methylsulfonyl-5-phenyl-4H-1,2,4-triazole (13B), and three kinds of 2-chloro-1,3-benzazoles (14-16Aa). *Based on the results summarized in Tables V and* VI, the following order of the reactivity can be demonstrated.

oxadiazole > thiadiazole >> triazole (at the 2-position)

benzoxazole = benzothiazole >> benzimidazole (at the 2-position)

Throughout the present investigation, it is concluded that phenylacetonitrile is the most effective nucleophile, and that the reactivity of 1,3-azoles and related compounds at the 2-position is closely associated to the *electronegativity of* heteroatoms (-X-) in these rings.

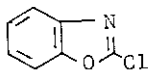
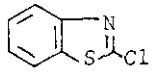
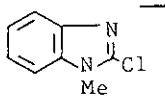
Table V. Reaction of 2-Methylsulfonyl-1,3,4-diazoles and 3-Methylsulfonyl-4H-1,2,4-triazole with Active Methylene Compounds

Substrate	Nucleophile	$^-CH(CN)Ph$ (Ca)	$^-CH(CN)_2$ (Cb)	$^-CH(CN)CO_2Et$ (Cc)	$^-CH(CO_2Et)_2$ (Cd)	$^-CH(COMe)_2$ (Ce)
	Time (h)	1/12	1/4	1	4	8
	mp (°C)	95-96	220(dec.)	220-221	67-68	86-88
11B	Yield (%)	78	87	84	71	68
	Time (h)	1/12	1/4	2	10	24
	mp (°C)	121-122	237(dec.)	218-220	143-145[a]	
12B	Yield (%)	81	82	76	80	0 (81)[b]
	Time (h)	1/4	24	24		
	mp (°C)	129-130				
13B	Yield (%)	83	0 (80)[b]	0 (76)[b]		

a) Lit.[5] mp 145-146°C.

b) The figures in the parentheses show the recoveries of substrates.

Table VI. Reaction of 2-Chloro-1,3-benzazoles with Active Methylene Compounds

Substrate	Nucleophile	$^-CH(CN)Ph$ (Ca)	$^-CH(CN)_2$ (Cb)	$^-CH(CN)CO_2Et$ (Cc)	$^-CH(CO_2Et)_2$ (Cd)	$^-CH(COMe)_2$ (Ce)
	Time (h)	1/4	4	6	20	24
	mp (°C)	111-112	270(dec.)	218-219	syrup	
14Aa	Yield (%)	70	72	60	39	0 (81)[a]
	Time (h)	1/4	4	8	20	24
	mp (°C)	114-116[b]	303(dec.)[c]	241-242[d]	140-142[e]	
15Aa	Yield (%)	73	76	58	42	0 (72)[a]
	Time (h)	1/4	24	24		
	mp (°C)	148-149				
16Aa	Yield (%)	83	0 (64)[a]	0 (69)[a]		

a) The figures in the parentheses show the recoveries of substrates.

b) Lit.[2] mp 110°C. c) Lit.[6] mp 295°C. d) Lit.[6] mp 243°C. e) Lit.[2] mp 148°C.

EXPERIMENTAL

All melting points were determined by capillary method and are uncorrected. Proton magnetic resonance (^{1}H-nmr) spectra were recorded at either 60 MHz on a JEOL JNM-PMX 60 spectrometer or at 100 MHz on a JEOL FX-100 spectrometer. Chemical shifts are quoted in δ value (ppm) with tetramethylsilane (TMS) or 2,2-dimethyl-2-silapentanesulfonic acid sodium salt (DSS) as an internal standard, and coupling constants (J) are given in hertz (Hz). The following abbreviations are used: s=singlet, d=doublet, t=triplet, q=quartet, m=multiplet, and br=broad. Infrared (ir) spectra were produced on a JASCO IR 810 spectrometer. Column chromatography was carried out on silica gel (NAKARAI CHEMICALS, Ltd. silica gel 60; KATAYAMA CHEMICALS, Ltd. silica gel 60).

4-Chloro-2,5-diphenylthiazole (5Aa) ——— A mixture of 2,5-diphenylthiazole (1.2 g, 5.0 mmol), N-chlorosuccinimide (NCS) (0.84 g, 6.3 mmol), and benzoyl peroxide (0.12 g, 0.5 mmol) in CCl_4 (15 ml) was refluxed for 45 h. After cooling, the mixture was filtered, and the filtrate was concentrated to dryness under reduced pressure. The residual solid was recrystallized from hexane to give colorless needles (1.0 g, 74%). mp 58-60°C . ^{1}H-Nmr ($CDCl_3$-TMS): 8.0-7.9 (m), 7.9-7.6 (m), 7.6-7.3 (m); the integrated ratio is 1:1:3.

4-Bromo-2,5-diphenylthiazole (5Ab) ——— A mixture of 2,5-diphenylthiazole (1.2 g, 5.0 mmol) and N-bromosuccinimide (1.1 g, 6.2 mmol) in CCl_4 (15 ml) containing 48% HBr (a few drops) was refluxed for 30 h. After cooling, the mixture was filtered, and the filtrate was washed with sat. NaCl solution, dried over K_2CO_3, and evaporated. The residue was recrystallized from hexane to give colorless needles (1.4 g, 89%). mp 60-62°C . ^{1}H-Nmr ($CDCl_3$-TMS): 8.1-7.9 (m), 7.9-7.6 (m), 7.6-7.4 (m); the integrated ratio is 1:1:3.

5-Chloro-2,4-diphenyloxazole (6Aa) ——— 2,4-Diphenyloxazole (1.1 g, 5.0 mmol) was treated with NCS (0.84 g, 6.3 mmol) as described for the preparation of 5Aa; reaction time was 5 h. Recrystallization from hexane gave colorless needles (0.93 g, 73%). mp 87-88°C. ^{1}H-Nmr ($CDCl_3$-TMS): 8.2-7.9 (m), 7.7-7.4 (m); the integrated ratio is 2:3.

5-Chloro-2,4-diphenylthiazole (7Aa) ——— 2,4-Diphenylthiazole (1.2 g, 5 mmol) was treated with NCS (0.84 g, 6.3 mmol) as described for the preparation of **5Aa**; reaction time was 5 h. Recrystallization from hexane gave colorless needles (1.0 g, 74%). mp 64-65°C. ^{1}H-Nmr ($CDCl_3$-TMS): 8.2-7.9 (m), 7.7-7.4 (m); the integrated ratio is 2:3.

1-Methyl-2-methylsulfonyl-4,5-diphenylimidazole (3B) ——— To a solution of 1-methyl-2-methylthio-4,5-diphenylimidazole (5.6 g, 20 mmol) in AcOH (20 ml) and acetone (200 ml), $KMnO_4$ (6.4 g, 40 mmol) was added , and the mixture was stirred for 4 h at room temperature. Aqueous $NaHSO_3$ solution was added to the mixture, then the whole was poured into H_2O (2.5 l). The separated solid was collected by suction, washed well with H_2O, and dissolved in $CHCl_3$. The $CHCl_3$ solution was dried over Na_2SO_4 and evaporated. The residue was recrystallized from AcOEt to give colorless prisms (5.8 g, 93%). mp 204-206°C. ^{1}H-Nmr ($CDCl_3$-TMS): 7.7-7.1 (m, 10H), 3.79 (s, 3H), 3.51 (s, 3H).

General Procedure for the Reaction of 1,3-Azoles with Active Methylene Compounds ——— A 60% oil dispersion of NaH (0.16 g, 4 mmol) was washed with hexane and suspended in dry THF (15 ml). An active methylene compound (4 mmol) was added to the THF suspension, and the mixture was stirred at room temperature (in the case of phenylacetonitrile; refluxed) for 15 min. Then a 1,3-azole derivative (2 mmol) in dry THF (5 ml) was added, and the mixture was refluxed until the substrate was disappeared (monitored by tlc). After removal of the THF under reduced pressure, the residue was diluted with H_2O, and the aqueous solution was neutralized with dil. HCl and extracted with $CHCl_3$ (in the case of malononitrile, separated crystals were collected by suction, washed with H_2O, and dried in air). The $CHCl_3$ solution was washed with H_2O, dried over $MgSO_4$, and evaporated. Recrystallization from an appropriate solvent gave the product.

Reaction of 7Ab with Sodium Methylthiolate ——— A solution of **7Ab** (0.63 g, 2 mmol) and 15% NaSMe (2 ml, 4 mmol) in EtOH (15 ml) was refluxed for 1 h. After removal of the solvent, the residue was subjected to silica gel column chromatography. Elution with hexane-AcOEt (9:1) gave 4,5-diphenylthiazole which was recrystallized from EtOH. Yield (0.42 g, 88%). mp 92-93°C. ^{1}H-Nmr ($CDCl_3$-TMS): 8.1-7.9 (m, 4H), 7.6-7.3 (m, 7H).

Table VII. Spectral Data for the Products of the Reaction of 1,3-Azole Derivatives with Active Methylene Compounds

No.	Ir ($CHCl_3$) cm^{-1}	^1H-Nmr ($CDCl_3$) ó (ppm)
1Ca	2250	7.8-7.3(m,15H),5.49(s,1H)
1Cb	3230,2230,2200[a]	7.52(br s),7.39(br s)[b,c]
1Cc	3330,2210,1670	14.4-14.1(br,1H),7.7-7.3(m,10H),4.28(q,J=7,2H), 1.37(t,J=7,3H)
1Cd	1740	7.9-7.3(m,10H),5.10(s,1H),4.36(q,J=7,4H),1.35(t,J=7,6H)
1Ce	3580	17.36(s,1H),7.9-7.3(m,10H),2,31(s,6H)
2Ca	2250	7.7-7.3(m,15H),5.59(s,1H)
2Cb	3100,2210,2190[a]	14.0-13.2(br,1H),7.6-7.0(m,10H)[b]
2Cc	3330,2200,1650[a]	12.3-12.0(br,1H),7.6-7.2(m,10H),4.32(q,J=7,2H), 1.39(t,J=7,2H)[b]
2Cd	1620	12.3-11.7(br,1H),7.5-7.4(m,10H),4.37(q,J=7,2H), 4.32(q,J=7,2H),1.39(t,J=7,6H)
3Ca	2250	7.7-7.1(m,15H),5.78(s,1H),3.26(s,3H)
4Ca	2250	8.3-8.1(m,2H),7.8-7.3(m,13H),5.52(s,1H)
5Ca	2250	8.1-7.9(m,2H),7.6-7.2(m,13H),5.35(s,1H)
6Ca	2250	8.3-8.0(m,2H),7.8-7.3(m,13H),5.64(s,1H)
7Ca	2250	8.1-7.8(m,2H),7.8-7.3(m,13H),5.60(s,1H)
8Ca	2260	7.78(d,J=3,1H),7.7-7.4(m,5H),7.32(d,J=3,1H),5.57(s,1H)
8Cb	2220,2180[a]	15.0-13.8(br,1H),7.38(d,J=4,1H),7.22(d,J=4,1H)[b]
8Cc	2200,1640	13.1-12.7(br,1H),7.41(d,J=4,1H),7.14(d,J=4,1H), 4.19(q,J=7,2H),1.27(t,J=7,3H)
8Cd	1640	13.6-13.3(br,1H),7.22(dd,J=4,J=2,1H),6.73(dd,J=5,J=2,1H), 4.29(q,J=7,6H),1.38(t,J=7,4H)
9Ca	2250	8.68(d,J=1,1H),7.8-7.3(m,5H),7.34(d,J=1,1H),5.38(s,1H)
10Ca	2250	8.64(s,1H),7.8-7.4(s,1H),5.61(s,1H)
11Ca	2260	8.2-7.9(m,2H),7.7-7.4(m,8H),5.67(s,1H)
11Cb	3100,2240,2210[a]	7.9-7.7(m,2H),7.6-7.4(m,3H)[b]

Table VII. continued

No.	Ir ($CHCl_3$) cm^{-1}	^1H-Nmr ($CDCl_3$) δ (ppm)
11Cc	2210,1680[a]	12.7-11.5(br,1H),8.2-7.5(m,5H),4.32(q,J=7,2H), 1.26(t,J=7,3H)[b]
11Cd	1760,1740	8.3-7.9(m,2H),7.7-7.4(m,3H),5.21(s,1H),4.35(q,J=7,4H), 1.33(t,J=7,6H)
11Ce	3580	17.6-17.4(br,1H),8.3-8.0(m,2H),7.7-7.5(m,3H),2.29(s,6H)
12Ca	2260	8.1-7.8(m,2H),7.7-7.3(m,8H),5.80(s,1H)
12Cb	3150,2220,2200[a]	7.9-7.7(m,2H),7.6-7.4(m,3H)[b]
12Cc	2220,1660	7.9-7.7(m,2H),7.6-7.4(m,3H),4.21(q,J=7,2H), 1.22(t,J=7,3H)[b]
12Cd	1640	13.7-13.5(br,1H),8.0-7.7(m,2H),7.6-7.4(m,3H), 4.32(q,J=7,4H),1.34(t,J=7,6H)
13Ca	2260	7.7-7.4(m,10H),5.89(s,1H),3.49(s,3H)
14Ca	2260	7.9-7.3(m,9H),5.54(s,1H)
14Cb	3100,2230,2210[a]	7.7-7.5(m,1H),7.4-7.1(m,3H)[b]
14Cc	2220,1680	11.3-11.0(br,1H),7.7-7.3(m,4H),4.31(q,J=7,2H)
14Cd	1740	8.8-7.2(m,4H),5.13(s,1H),4.33(q,J=7,4H),1.32(t,J=7,6H)
15Ca	2260	8.0-7.7(m,1H),7.7-7.1(m,8H),5.64(s,1H)
15Cb	3170,2220,2180[a]	8.0-7.8(m,1H),7.6-7.2(m,3H)[b]
15Cc	2210,1660	13.4-13.0(br,1H),8.1-7.8(m,4H),7.7-7.3(m,3H), 4.26(q,J=7,2H),1.31(t,J=7,3H)
15Cd	1690,1650	13.5-13.2(br,1H),7.8-7.5(m,1H),7.5-7.1(m,3H), 4.35(q,J=7,4H),1.42(t,J=7,6H)
16Ca	2260	8.0-7.7(m,1H),7.5-7.3(m,8H),5.76(s,1H),3.62(s,3H)

a) KBr. b) DMSO-d_6. c) The integrated ratio is 1:1.

Table VIII. Analytical Data for All New Compounds

No.	Formula	Analysis (%)							
		Calcd				Found			
		C	H	N	S	C	H	N	S
5Aa	$C_{15}H_{10}NClS$	66.29	3.71	5.15	11.80	65.99	3.84	5.08	11.96
5Ab	$C_{15}H_{10}NBrS$	56.97	3.19	4.43	10.14	56.86	3.12	4.41	10.23
6Aa	$C_{15}H_{10}NOCl$	70.46	3.94	5.48		70.25	3.71	5.71	
7Aa	$C_{15}H_{10}NClS$	66.29	3.71	5.15	11.80	66.54	3.78	5.07	11.69
3B	$C_{17}H_{16}N_2O_2S$	65.36	5.16	8.97	10.26	65.15	5.19	9.07	10.57
1Cb	$C_{18}H_{11}N_3O$	75.78	3.89	14.73		75.56	4.11	14.60	
1Cc	$C_{20}H_{16}N_2O_3$	72.28	4.86	8.43		71.96	5.05	8.19	
1Cd	$C_{22}H_{21}NO_5$	69.65	5.58	3.69		69.21	5.51	3.48	
1Ce	$C_{20}H_{17}NO_3$	75.22	5.37	4.39		75.23	5.48	4.23	
2Ca	$C_{23}H_{16}N_2S$	78.38	4.58	7.95	9.10	78.55	4.68	7.92	9.26
2Cb	$C_{18}H_{11}N_3S$	71.74	3.68	13.94	10.64	71.62	3.88	13.85	10.60
2Cc	$C_{20}H_{16}N_2O_2S$	68.94	4.63	8.04	9.20	68.64	4.67	7.76	9.21
2Cd	$C_{22}H_{21}NO_4S$	66.82	5.35	3.54	8.11	67.04	5.41	3.49	8.19
3Ca	$C_{24}H_{19}N_3$	82.49	5.48	12.03		82.84	5.79	12.14	
4Ca	$C_{23}H_{16}N_2O$	82.12	4.79	8.33		82.37	4.96	8.12	
5Ca	$C_{23}H_{16}N_2S$	78.38	4.58	7.95	9.10	78.40	4.62	7.81	9.33
6Ca	$C_{23}H_{16}N_2O$	82.12	4.79	8.33		82.37	5.03	8.48	
7Ca	$C_{23}H_{16}N_2S$	78.38	4.58	7.95	9.10	78.35	4.54	7.89	9.17
8Cb	$C_6H_3N_3S$	48.31	2.03	28.17	21.49	48.31	2.16	28.00	21.63
8Cc	$C_8H_8N_2O_2S$	48.97	4.11	14.27	16.34	48.75	3.87	14.03	16.33
8Cd	$C_{10}H_{13}NO_4S$	49.37	5.39	5.76	13.18	49.56	5.30	5.71	13.35
9Ca	$C_{11}H_8N_2S$	65.97	4.03	13.99	16.01	66.11	4.11	13.84	15.82
10Ca	$C_{11}H_8N_2S$	65.97	4.03	13.99	16.01	65.84	4.16	13.81	15.79
11Ca	$C_{16}H_{11}N_3O$	73.55	4.24	16.08		73.60	4.28	15.95	
11Cb	$C_{11}H_6N_4O$	68.03	3.11	28.85		67.78	3.35	28.59	
11Cc	$C_{13}H_{11}N_3O_3$	60.70	3.92	16.33		60.81	4.00	16.20	
11Cd	$C_{15}H_{16}N_2O_5$	59.21	5.30	9.21		59.15	5.33	8.95	
11Ce	$C_{13}H_{12}N_2O_3$	63.93	4.95	11.47		63.90	4.92	11.31	

Table VIII. continued

No.	Formula	Analysis (%)							
		Calcd				Found			
		C	H	N	S	C	H	N	S
12Ca	$C_{16}H_{11}N_3S$	69.29	4.00	15.15	11.56	69.09	4.04	15.23	11.63
12Cb	$C_{11}H_6N_4S$	58.39	2.67	24.76	14.17	58.49	2.85	24.61	13.84
12Cc	$C_{13}H_{11}N_3O_2S$	57.13	4.06	15.37	10.04	57.36	3.85	15.24	9.81
13Ca	$C_{17}H_{14}N_4$	74.43	5.14	20.42		74.42	5.22	20.42	
14Ca	$C_{15}H_{10}N_2O$	76.91	4.30	11.96		76.69	4.51	11.76	
14Cb	$C_{10}H_5N_3O$	65.57	2.75	22.94		65.37	2.66	22.81	
14Cc	$C_{12}H_{10}N_2O_3$	62.61	4.38	12.17		62.43	4.47	11.96	
14Cd	$C_{14}H_{15}NO_5$	60.64	5.45	5.05		60.91	5.57	4.88	
15Ca	$C_{16}H_{13}N_3$	77.71	5.30	16.99		77.92	5.56	16.84	

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